Web appendix A Forces acting against the cyclist

Gravity

$$U = mgh$$

U= gravitational potential energy (Joules)
m= mass (Kg)
g= gravity (9.8m/sec/sec)
h= distance (metres)

The difference in weight between the two cycles is 4Kg. The rider weighs the same, 76Kg. This means that the energy expended on lifting the steel bike and rider through 843 metres is (76+13.5) x 9.8 x 843 or about 740 Kilojoules. The energy for the carbon bike is (76 + 9.5)* 9.8 * 843, about 706 Kilo Joules.

Friction (Rolling resistance)

Rolling resistance is calculated as follows:

$$F = C_{rr}N_f$$

F = Force (newtons)
C_{rr} = Coefficient of rolling resistance (dimensionless)
N_f = Normal force, equal to weight

The coefficient of rolling resistance for a cycle tyre is about 0.0045 (1). Work done (joules) is equivalent to force (newtons) x distance (metres). So the rolling resistance of the steel bike will be about 0.0045 x (76 + 13.5) x 9.8 = 4 newtons and the rolling resistance of the carbon bike 0.0045 x (76+9.5) x 9.8 =3.8 newtons.

Work done overcoming rolling resistance:
Work done / time, is power.
The work done by the steel bike overcoming rolling resistance is 4 x 43416 (trip distance in metres)/ 6483 (average journey time in seconds) or 26 watts.
The extra work done in propelling the steel bike compared to the carbon bike against friction as 0.2 x 43416 / 6483 which equates to 1.2 watts.

Drag

The power required to overcome drag is expressed by the following formula:

$$\tfrac{1}{2}\rho v^3 A C_d$$

ρ = density of the fluid (air)
v = velocity
A = referenced area
C_d = drag coefficient

If I present a surface area of $1m^2$ to the direction of travel and my average velocity is 24 kilometres/hour (6.6 m/second or 15 miles/hour) . The density of air is $1.2kg/m^3$ and the drag coefficient for a cyclist on a touring bike is 1(4). This gives the power necessary to overcome drag at this speed as $0.5 \times 1.2 \times 6.7^3 \times 1 \times 1$ or 170 watts.

References

1. Wilson et al. Bicycle Science p188. 3rd Edition. MIT P, 2004